EDUCATION

SOUND WAVE CONTROLLER

SC-500

Ultrasonic generator with accessories

for the Debye-Sears experiment and

for demonstrating standing ultrasonic waves.

User Manual

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gaMPT ULTRASONIC SOLUTIONS

Safety instructions

Before switching on the ultrasonic generator and accessories, carefully read the following instructions for the sake of your safety and for the safety of the equipment.

- The slits in the device are for ventilation and must be kept clear to avoid overheating the equipment. It is recommended that the device is placed on its own stand (also included).
- Before switching on the device make sure that it is adjusted to the main voltage you intend to use. Make sure that you keep within the operating specifications.
- Never try to push objects through the slits in the device since this could cause short circuits or electric shocks.
- Only use GAMPT ultrasonic transducers with the “PROBE” connection. Be careful, voltages may be as high as 70 V.
- Do not use the ultrasonic transducer for a lengthy period without contact to fluids. Otherwise the transducer may overheat and be destroyed.
- Do not turn on the SC500 laser diode if there are people standing in the beam. This is a class II laser with power < 1 mW (red) or class IIIa with power < 5 mW (green). Do not look into the beam or aim it at other people or animals.
- Beware: high-powered ultrasound! Do not use the probe on people or animals.

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Content

1. Introduction **4**

2. Components **5**

2.1. Ultrasonic generator – operating elements 5

2.2. Set-up for SC500 test container 6

2.3. Lens on a glass slide 6

2.4. Laser module 6

3. Experimental procedure **7**

3.1. Debye-Sears-effect (PHY11) 7

3.2. Projection of standing ultrasonic waves (PHY12) 8

3.3. Concentration measurement (IND04) 9

3.4. General instructions for experiments 10

4. Technical details **11**

4.1. Ultrasonic generator 11

4.2. Ultrasonic transducer 11

4.3. Test container 11

4.4. Laser diode 11

4.5. Lens on glass slide 11

1. Introduction

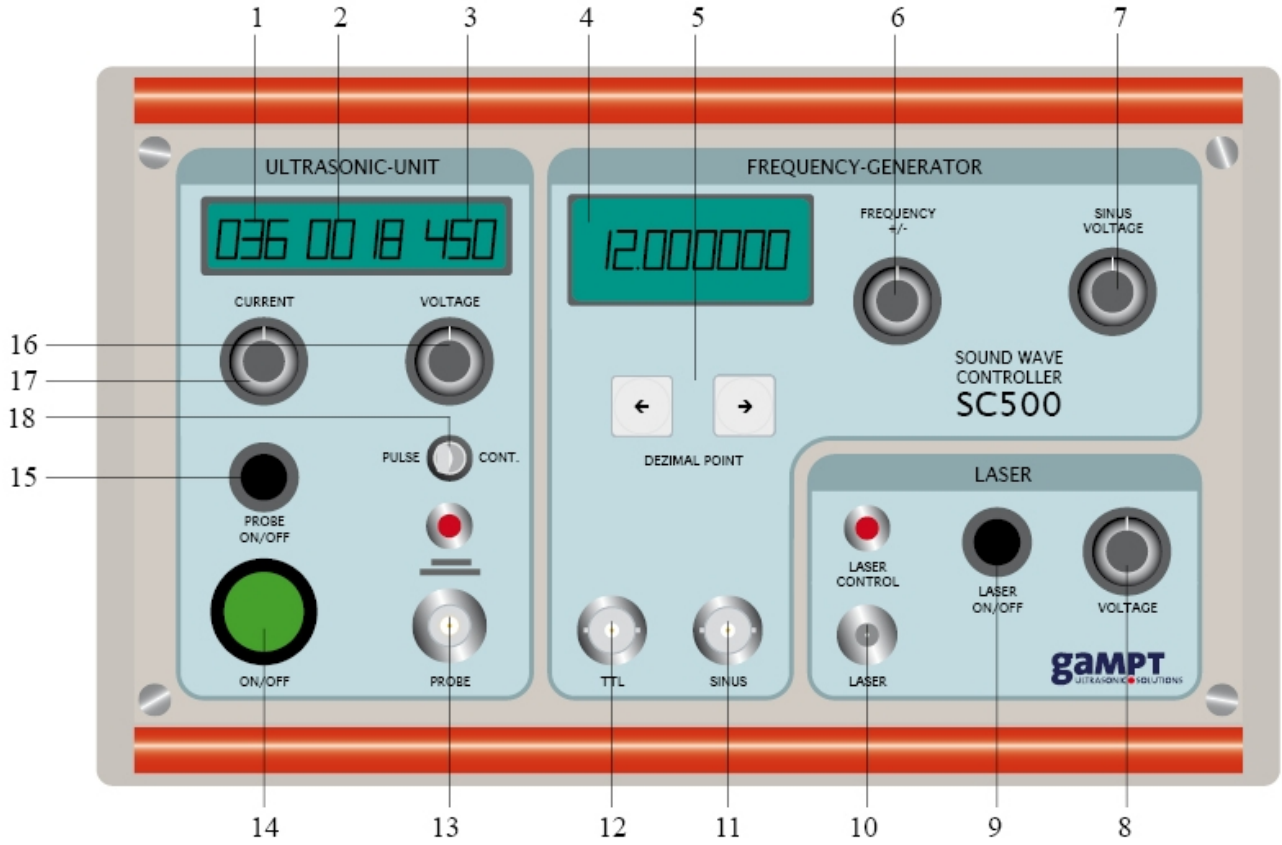
In 1932 Debye and Sears demonstrated for the first time how light is refracted when passing through a fluid excited to high-frequency oscillation. The maxima and minima in density act here like the grid elements of an optical diffraction grating. The grating constant corresponds to the ultrasonic wavelength and is thus dependent on the frequency of the ultrasound and the speed of sound in the medium through which the sound is travelling. The CW (continuous wave) generator with its accompanying broad-band ultrasonic transducer, along with an adjustable test vessel and its integrated laser holder, mean that it is possible for the first time to demonstrate this phenomenon to schoolchildren and college students alike using simple and compact equipment. The equipment can demonstrate both frequency dependence (with four different frequencies) and the ultrasonic wavelength in various fluids, allowing the speed of sound in the medium to be calculated. It is also possible to project standing ultrasonic waves by inserting an optical lens between the laser source and the ultrasonic waves. The waves are then projected by the diverging laser beam.

(1) SC 500 – Ultrasonic generator with laser diode output
(2) Laser diode
(3) Test container
(4) Ultrasonic transducer

2. Components

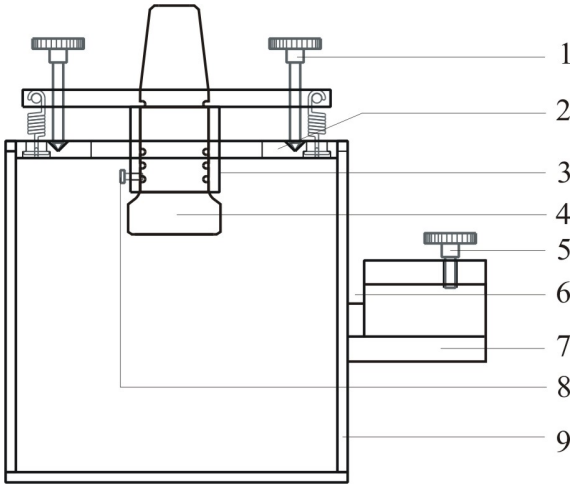
2.1. Ultrasonic generator – operating elements

The ultrasonic generator generates continuous high power ultrasonic waves (CW = continuous wave). Furthermore it can generate a sinus- or TTL signal with adjustable frequencies. An additionally adjustable voltage output can be used for the laser diode of the company GAMPT.
The transducer will be connected to the SC500 via socket (13). The ultrasonic power can be changed with the transducer voltage (16) between 4 and 45 V. The maximum reachable current depends from selected frequency and current restriction. The maximum current can be adjusted with the potentiometer (17) (max. value=320 mA). In the left LCD-display the values for current (1), voltage (3) and electrical power(2) are shown. The transducer outlet can be separately switched off (15), the status is shown with a led.
The frequency will be adjusted with an incremental switcher (6). The push buttons (5) serves to move the changeable decimal place position to right or left. The frequency is shown in the right display (4).
At the BNC outlets the frequency is given as rectangular TTL-signal (12) or as sine signal(11). The amplitude of the sine signal can be changed with controller (7). The laser diode will be connected via socket (10). The laser voltage can be modified with controller (8). The laser outlet can also be separately switched off (9).
With the switch Pulse/Cont (18) the SC500 can be used as pulse generator. In pulse mode no continuous signal (cw) but short pulses are created. The chosen transmitter frequency (4) represents now the repetition frequency. It has to be adjusted to the time of flight and must not be selected to high (< 10 kHz).



(1) display current transducer
(2) display power transducer
(3) display voltage transducer
(4) display frequency
(5) push button decimal point frequency
(6) adjustment frequency
(7) adjustment voltage sine output
(8) adjustment voltage laser output
(9) on/off laser output
(10) socket laser diode
(11) socket sine output (BNC)
(12) socket TTL output (BNC)
(13) socket ultrasonic transducer
(14) on/off SC500
(15) on/off transducer
(16) on/off voltage transducer
(17) adjustment current transducer

2.2. Set-up for SC500 test container

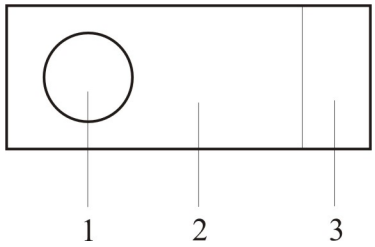


Standing ultrasonic waves are generated in a special container. It allows the angle of incidence of the waves to be set precisely to the perpendicular by means of a special holder for the ultrasonic transducer. The test container consists of a glass vessel with a lid and a holder for the transducer, three adjustment screws to set the alignment for the standing wave and a laser holder perpendicular to the axis of the waves which also has a holder for a lens so that the ultrasonic waves and the Debye-Sears effect can be projected.

(1) Adjustment screw for changing the angle of the transducer
(2) Lid
(3) Transducer holder
(4) Ultrasonic transducer (supplied with SC500)
(5) Securing screw for laser diode
(6) Slot for lens holder
(7) Laser holder
(8) Securing screw for ultrasonic transducer
(9) Glass container

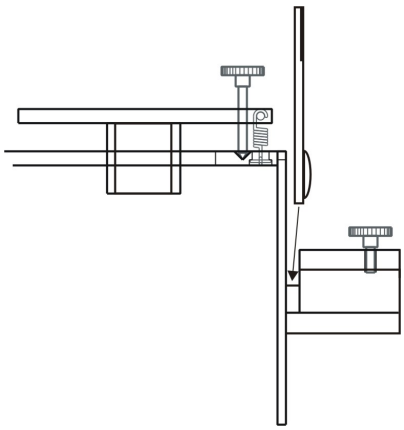
2.3. Lens on a glass slide

A plane-convex lens is attached to a rectangular slide. This is inserted into the slot in the laser holder of the test container for experiments involving projection.

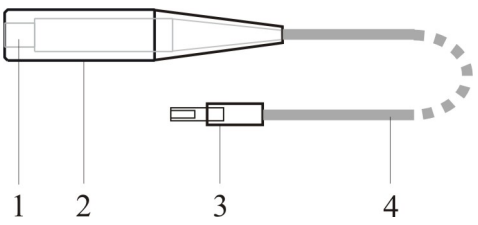


(1) Plano-convex lens
(2) Glass slide
(3) Grip

The following illustration shows how the lens should be properly placed in the test container



2.4. Laser module



Class II laser diode for demonstrating the Debye-Sears effect and projecting ultrasonic waves for use with the ultrasonic generator and test container.

(1) Laser beam window
(2) Laser module jacket
(3) Plug for connecting to the ultrasonic generator
(4) Connection lead

3. Experimental procedure

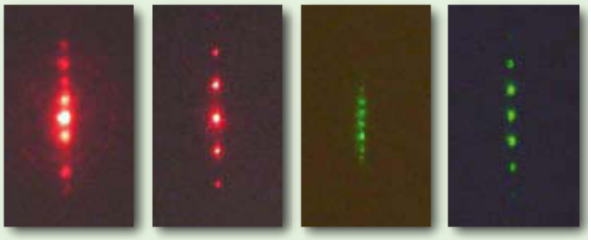
3.1. Debye-Sears-effect (PHY11)

Purpose:

The light diffraction at a progressing ultrasound wave can be demonstrated (Debye-Sears-effect). For this the dependance of the diffraction maxima on the wavelength of light (red and green) and on the frequency of the ultrasound will be investigated. From the geometry of the diffraction image the sound velocity of a test liquid (here distilled water) is determined.

Setup:

Ultrasound wave generator SC500	order no	GAMPT-20100
Multi frequency probe	order no	GAMPT-20138
Laser module red	order no	GAMPT-20210
Laser module green	order no	GAMPT-20211
Sample reservoir with laser support	order no	GAMPT-20225
Probe adjustment	order no	GAMPT-20224



Basics:

In 1932 Debye and Sears could show for the first time that light crossing a liquid that is excited by a high frequency oscillation undergoes a diffraction. The density maxima and minima of a standing or continuously progressing wave act like lattice elements of an optical diffraction lattice. The lattice constant corresponds to the wavelength of the ultrasound and therefore depends on their frequency and the sound velocity of the medium. From the diffraction images of the Debye-Sears experiment the wavelength of the sound wave can be determined and with that the sound velocity in the liquid can be calculated. Therefore the distance s between the ultrasound source and the diffraction image must be measured, the number N of diffraction maxima and the distance x between the -N th and +N th order of diffraction must be determined. From the known wavelength of the laser light l_L the wavelength of the ultrasound wave λ_S can then be calculated via (1).

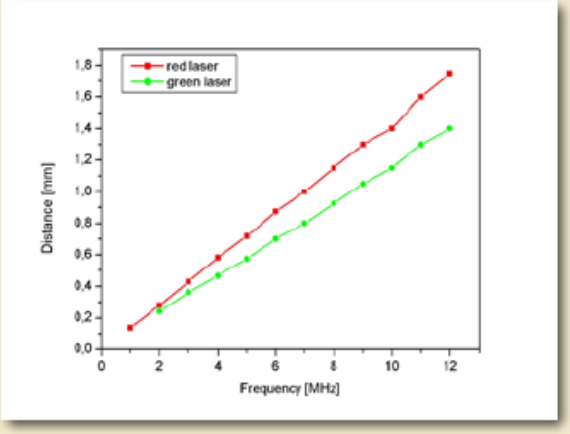
(1) $$\lambda_S = \frac{2\,N\,\lambda_L\,s}{x}$$

Procedure:

The distance s between the ultrasound transducer and the diffraction image is measured by a ruler. The maximum order of diffraction N is determined and the distance between the -Nth and the +Nth order of diffraction x is measured by a calliper or a ruler. The measuring is carried out for all frequencies in the range from 1 MHz on in 1MHz steps, as long as diffraction maxima are visible and separable. The measurement is performed for red as well as green laser light. From the measured values the wavelength of sound λ_S is determined after (1) and with the known frequency f the sound velocity c is obtained using $c = f * \lambda_S$.

Results:

As expected from equation (1) with increasing ultrasound frequency an increase of the distance of diffraction orders can be seen. When comparing the distances of diffraction orders for the same ultrasound frequency but different laser lights, red light gives larger distances. The number of diffraction order is determined mainly by the transmission characteristics of the probe and the frequency attenuation. The main error results from measuring the distances of the diffraction orders x. This can be reduced applying a larger distance s or a suitable optical projection. The mean sound velocity of 1479 m/s lies near the theoretical value of 1482 m/s at 20 C.



f [MHz]	N	x [cm]	x/(2N) [cm]	l_S	c [m/s]
1					
2	5	2,4	0,240	720,4	1441
3	4	2,9	0,363	477,0	1431
4	3	2,8	0,467	370,5	1482
5	2	2,3	0,575	300,7	1503
6	2	2,8	0,700	247,0	1482
7	2	3,2	0,800	216,1	1513
8	2	3,7	0,925	186,9	1495
9	2	4,2	1,050	164,7	1482
10	2	4,6	1,150	150,3	1503
11	1	2,6	1,300	133,0	1463
12	1	2,8	1,400	123,5	1482
				mean	1479
				SD	26

red laser: λ_L=652 nm, s=325 cm

f [MHz]	N	x [cm]	x/(2N) [cm]	λ_S	c [m/s]
1	9	2,5	0,139	1525,7	1526
2	5	2,8	0,280	756,8	1514
3	5	4,3	0,430	492,8	1478
4	3	3,5	0,583	363,3	1453
5	3	4,3	0,717	295,7	1478
6	2	3,5	0,875	242,2	1453
7	2	4	1,000	211,9	1483
8	2	4,6	1,150	184,3	1474
9	2	5,2	1,300	163,0	1467
10	1	2,8	1,400	151,4	1514
11	1	3,2	1,600	132,4	1457
12	1	3,5	1,750	121,1	1453
				mean	1479
				SD	26

green laser: λ_L=532 nm, s=325 cm

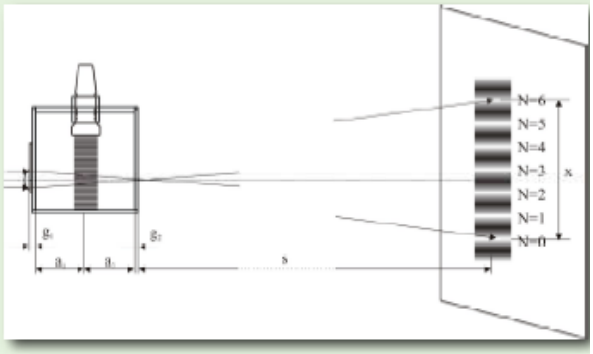
3.2. Projection of standing ultrasonic waves (PHY12)

Purpose:

Using divergent laser light the image of a standing ultrasound wave can be demonstrated. By means of the originating projection image the dependence on the wavelength of light (red and green) and on the frequency of the ultrasound wave is investigated. From the geometry of the projection image the velocity of sound of the test liquid (here distilled water) is determined.

Setup:

Ultrasound wave generator SC500	order no	GAMPT-20100
Multi frequency probe	order no	GAMPT-20138
Laser module red	order no	GAMPT-20210
Laser module green	order no	GAMPT-20211
Sample reservoir with laser support	order no	GAMPT-20225
Probe adjustment	order no	GAMPT-20224
Lens holder	order no	GAMPT-20230



Basics:

At exact alignment of the ultrasound probe to the bottom of the vessel a standing wave arises. This can be displayed in transmission with divergent light because the sound pressure generates periodic changes of the refraction index. On the screen the density distribution of the standing wave will be shown as modulation of brightness. The distance of brightness maxima follows from

(1) $$x = \frac{\lambda_s}{2} \frac{f - a_1 - g_1}{s - (f - a_1 - a_2 - g_1 - g_2)}$$

For the exact determination of the wavelength from the image and the geometry the refraction corrections through the glass walls and the measuring liquid have to be considered beside the focal distance f of the lens in air (concerning the geometry see the following scheme). Furthermore one has to consider, that by using monochromatic light the focal distance of the lens f as well as the refraction index are functions of the wavelength of light. For the exact determination of the wavelength the method of light diffraction is recommended as described in the experiment of Debye-Sears-effect.

The distance a_1 between the sound field and the glass wall on the side of the lens can be taken approximately as half the inner dimension of the vessel minus half of the transducer diameter (a_2 follows then from the inner dimension minus a_1, N is the number of brightness maxima and x the belonging distance). The sound velocity of the medium c follows from the frequency f after (2) as $c=\lambda_s * f$.

Procedure:

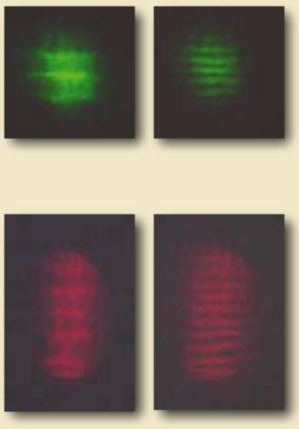
The lense support is inserted into the laser support and by that into the optical path. The distance between the edge of the vessel and the diffraction image s is measured by a ruler. The number of brightness maxima N is determined and the distance x is measured by a calliper or a ruler. The measurement is done for all frequencies in the range from 1 MHz on in steps of 1 MHz, as long as a projection image can be observed. The measurement is carried out for red as well as for green laser light. From the results of measurement the wavelength of sound λ_s is determined after (1) and using the known frequency f the velocity of sound c is determined after (2). The values are compared for the different laser wavelengths and deviations to values from the literature discussed.

Results:

a_1 = 4,05 cm a_2 = 5,65 cm s = 280 cm g_1 = 4,9 mm g_2 = 3,9 mm
f = 10 cm (with 652 nm red laser)
sound velocity of water: 1482 m/s at 20°C

f [MHz]	N	x [cm]	λ_s	c [m/s]
2	2	4,1	793	1626
3	3	4,0	529	1586
4	4	4,0	407	1586
green			mean	1573

f [MHz]	N	x [cm]	λ_s	c [m/s]
2	4	7,7	763	1527
3	7	9,0	510	1530
4	7	6,9	391	1564
red			mean	1540



Red laser: l=652 nm, Green laser: l=532 nm
As expected from equation (1) the distance of brightness maxima decreases with increasing ultrasound frequency. The determined sound velocity value is always too large and is larger for green light too. This error results from the change of the focal length of the lens due to transmission through the glass plates and the measuring liquid. The difference between green and red light is explained by the wavelength dependence of the refraction indices.

3.3. Concentration measurement (IND04)

Purpose:

The dependence of sound velocity of a salt solution on the concentration is determined by means of the Debye-Sears-effect and is compared with an empirical equation for the sound velocity in sea water after Mackenzie.

Setup:

Ultrasound wave generator SC500	order no	GAMPT-20100
Multi frequency probe	order no	GAMPT-20138
Laser module red	order no	GAMPT-20210
Sample reservoir with laser support	order no	GAMPT-20225
Probe adjustment	order no	GAMPT-20224
Salt, stirrer, thermometer		

Basics:

With increasing concentration in electrolytes a decrease of compressibility arrives. This leads to a concentration dependent increase of the sound velocity.
From the diffraction patterns of the Debye-Sears-experiment (PHY11) the wavelength of the sound wave can be determined and with that the sound velocity of the liquid can be calculated. The distance between the ultrasound source and the diffraction patterns has to be measured, the number of diffraction maxima N and the distance between the -Nth and the +Nth diffraction order x must be determined. From the known wavelength of the laser light λL then the wavelength of the ultrasound wave λS can be calculated:

(1) $$\lambda_s = \frac{2N\lambda_L s}{x}$$

The empirical formula for the sound velocity in sea water after Mackenzie (JASA, 70,807-12) is:

(2) $$c = 1448.96+4.591*T-0.05304*T^2+0.0002374*T^3 +1.34*(S-35)-0.01025*T*(S-35)$$

With T = temperature [°C], S = concentration of salt [g salt/kg sea water.

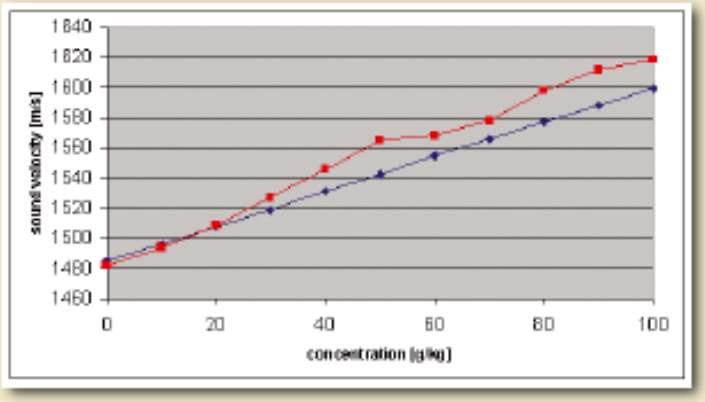
Procedure:

The distance between the ultrasound transducer and the diffraction pattern s is measured by a tape. The maximal diffraction order N is determined and the distance between the -Nth and the +Nth diffraction order x is measured by a caliper. The measuring is carried out for a frequency with a large distance of diffraction maxima and still sufficient number of maxima e.g. 9 MHz and with the red laser (larger diffraction distance). From the results of measurements after (1) the wavelength of sound λs is determined and with the known frequency f the sound velocity c is calculated by c=f*λs. A respective amount of rock salt is added in order to enhance the concentration stepwise from 0 to 10 mass per cent. After complete solution the measurement is repeated. The temperature of the solution is measured in order to take into account the dependence of the sound velocity on temperature. The measured and after (1) calculated sound velocities are plotted versus the concentration.

Results:

distance s=3220 mm frequency f=9,0 MHz wave length red laser λ_L=652 nm N=2

S [g/kg]	x [mm]	λ_s [µm]	c mess [m/s]	c (2) [m/s]	T [°C]
0	51	164,7	1482	1485	21
10	50,6	166,0	1494	1496	21
20	50,1	167,6	1509	1507	21
30	49,5	169,7	1527	1519	21
40	48,9	171,7	1546	1531	21,5
50	48,3	173,9	1565	1542	21,5
60	48,2	174,2	1568	1555	22
70	47,9	175,3	1578	1566	22
80	47,3	177,5	1598	1577	22
90	46,9	179,1	1612	1588	22
100	46,7	179,8	1618	1599	22



The sound velocity increases clearly with the increasing concentration of the salt solution and shows in the measuring range (0 - 10% (g/g)) an almost linear dependence. The measured values (red curve) agree in the range of small concentrations (< 3%) with the theoretical values.

3.4. General instructions for experiments

Pay attention to the following instructions for the experiment to work:

- Use water that contains as little air as possible since air bubbles disturb both the ultrasonic field and the refraction of the laser beam.
- Any air bubbles around the probe should be removed.
- Allow for the maximum distance between the test container and the projection screen.
- When no measurements are being made, the ultrasound should be switched off so that the test fluid does not heat up.
- For precise measurements, also measure the temperature and include this in the comparison.
- When using high voltage at any frequency and when the transducer is properly aligned, at least 3 orders of diffraction should be visible.
- The projection experiment is much more sensitive to the angle of the transducer than the refraction experiment. Therefore the conditions for generating standing waves must be stable and very precise.

4. Technical details

4.1. Ultrasonic generator

Frequency:	adjustable 0,1 Hz – 20 MHz, (step size 1 Hz)
Output signal:	Sine wave, continuously adjustable between 4 Vpp to approximately 45 Vpp. Can be switched off. Red control light, current restriction adjustable (max. value 320 mA)
Display:	16-digit LCD for voltage, current and power 8-digit LCD for frequency
Monitor signal:	Frequency signal, TTL level: 5 $_{SS}$
Sinus signal:	Sinus max : 4 V_{SS}
Laser output:	3 V DC, max. 300 mW at socket 5.5 mm outer Ø, 2.5 mm inner Ø, Can be switched off. Red control light
Dimensions:	256 x 86 x 156 mm
Main voltage:	115/230 V, 50/60 Hz
Power consumption	max. 60 VA; 5 VA minimum power (laser and ultrasound switched off)
Fuse:	T 315 mA (230 V) T 630 mA (115 V)

4.2. Ultrasonic transducer

Probe diameter:	27 mm
Active surface area:	2 cm²
Cable length:	1 m

4.3. Test container

Test vessel:	100 x 100 x 120 mm
Volume:	ca. 900 ml
Laser holder:	17 mm internal diameter
Transducer holder:	adjustable, designed for the supplied transducer

4.4. Laser diode

Beam spot:	<6 mm at 3 m
Wave length:	650 nm
Power:	red: <1 mW, laser safety class II green: <5 mW, laser safety class IIIa
Supply voltage:	3 V DC
Current consumption:	max. 35 mA
Connecting plug:	1 m cable with plug of 5,5 mm outer-Ø, 2,5 mm inner-Ø
Dimensions:	80 mm x 17 mm Ø

4.5. Lens on glass slide

Lens slide:	76 mm x 26 mm glass slide with roughened gripping surface
Lens:	plano-convex, f=100 mm (in air), 16 mm Ø